APPLICATION FOR UNITED STATES LETTERS PATENT

For

METHODS AND APPARATUSES FOR FILTERING COMMON MODE
INTERFERENCE

by

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EXPRESS MAIL MAILING LABEL
NUMBER EV 323285508 US
DATE OF DEPOSIT July 25, 2003

CROSS-REFERENCE(S) TO RELATED APPLICATION(S)

This application claims priority to U.S. Provisional Patent Application Serial No. 60/437,171, filed December 13, 2002, the entire contents of which are expressly incorporated by reference.

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REFERENCE TO APPENDIX

This application includes a computer program listing appendix, submitted on compact disc (CD). The content of the CD is incorporated by reference in its entirety and accordingly forms a part of this specification. The CD contains the following file:

File name: full7function.txt   File Size: 35.1 kb

10   Creation date for CD: June 25, 2003

BACKGROUND OF THE INVENTION

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1.   Field of the Invention

The invention relates generally to the field of signal processing. More particularly, the invention relates to a method and apparatus for filtering common mode

20   interference.

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2. Discussion of the Related Art

Typically, multi-channel navigation systems include an array of sensors (or transducers) and signal conditioning elements for detecting analog signals and generating digital data for further processing by a guidance processor. The guidance processor can

5   determine the position of a signal source based on the received information while using parameters characteristic of the array. A multi-channel navigation system may be, for example, a multi-channel laser seeker.

A multi-channel laser seeker receives laser pulses on a few of its multiple channels, and uses this data to determine the direction or position of a laser source. In

10   practice, the seeker receives data only on a small subset of its channels for any given laser pulse, while the other channels are near zero on their response.

Unfortunately, multi-channel laser seekers may be subject to electrical interference that may appear as large signals on most or all channels simultaneously. The electrical interference may be in the form of pulses and, when the average pulse repetition

15   frequencies (PRF) is high, it may severely degrade the seeker's performance.

SUMMARY OF THE INVENTION

In one embodiment, the invention is a method that includes detecting a level on each of a plurality of data channels; summing the levels of a subset of data channels to get a summed level, the subset of data channels containing the lowest levels present in the

20   plurality of data channels; comparing the summed level with the highest level present in the plurality of data channels; and rejecting a common mode interference in each of the

plurality of data channels if the summed level exceeds the highest level present in the plurality of data channels. Other embodiments of the present methods are described below.

In another embodiment, the invention is an apparatus that includes a plurality of data channels; an array of input filters coupled to the plurality of data channels; a pulse detection circuit coupled to the array of input filters; a common mode rejection circuit coupled to the pulse detection circuit, the common mode rejection circuit operable to sum the levels of a subset of data channels to get a summed level, the subset of data channels containing the lowest levels present in the plurality of data channels, compare the summed level with the highest level present in the plurality of data channels, and reject a common mode interference in each of the plurality of data channels if the summed level exceeds the highest level present in the plurality of data channels; and a pulse data queuing and transmission circuit coupled to the common mode rejection circuit. Other embodiments of the present apparatuses are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings demonstrate aspects of the present methods and apparatuses. They illustrate by way of example and not limitation. Like reference numbers refer to similar elements. The features illustrated in the drawings are not necessarily drawn to scale.

FIGS. 1A-B show a block diagram of one embodiment of a common mode interference processing system suitable for use with the present method and apparatuses.

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FIG. 2 shows a flowchart of one embodiment of a common mode interference filtering method suitable for use with the present method and apparatuses.

FIG. 3 shows a graph of filtered and unfiltered simulated data streams, illustrating an aspect of the invention.

5 <u>**DETAILED DESCRIPTION**</u>

In this document (including the claims), the terms "comprise" (and any form of comprise, such as "comprises" and "comprising"), "have" (and any form of have, such as "has" and "having"), and "include" (and any form of include, such as "includes" and "including") are open-ended linking verbs. For example, a method "comprising"

10 detecting a level on each of a plurality of data channels; summing the levels of a subset of data channels to get a summed level; comparing the summed level with the highest level present in the plurality of data channels; and rejecting a common mode interference in each of the plurality of data channels if the summed level exceeds the highest level present in the plurality of data channels is a method that possesses at least these steps, but

15 is not limited to possessing only these steps.

Similarly, an apparatus "comprising" a plurality of data channels; an array of input filters coupled to the plurality of data channels; a pulse detection circuit coupled to the array of input filters; a common mode rejection circuit coupled to the pulse detection circuit; and a pulse data queuing and transmission circuit coupled to the common mode

20 rejection circuit is an apparatus that possesses at least these structures, but is not limited to possessing only these structures. For example, this apparatus also covers an apparatus

that possesses a guidance circuit coupled to the pulse data queuing and transmission circuit.

The terms "a" and "an" are defined as one or more than one. The term "another" is defined as at least a second or more. The term "plurality" is defined as two or more than two. The term "coupled" is defined as connected, although not necessarily directly, and not necessarily mechanically. The term "program" or "computer program" is defined as a sequence of instructions designed for execution on a computer system.

Those of ordinary skill in the art will appreciate that in the detailed description below, certain well known components and assembly techniques have been omitted so that the invention is not obscured in unnecessary detail.

The invention may include a method and apparatus for filtering a common mode interference embedded in a plurality of data streams. In one exemplary embodiment, the invention may include a digital front-end that removes a common mode interference from the plurality of data streams before the data is sent to a pulse processor or a guidance circuit. In another embodiment, the invention may include rejecting a common mode interference in a multi-channel laser seeker to determine the direction or position of a laser source. The laser seeker may have, for example, seven data channels. Such systems may find a variety of applications including, for example, navigation and automated projectile maneuvering.

Typically, a multi-channel laser seeker receives data only on a small subset of its channels for any given laser pulse, while the other channels are near zero on their response. Nevertheless, the seeker may be subject to electrical interference on most or all

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channels simultaneously. The invention may include identifying and rejecting common mode interference in a plurality of channels with a digital front-end.

Referring to **FIGS. 1A-B**, a block diagram of one embodiment of a common mode interference processing system **100** is depicted. Plurality of digitized data channels

5 **101** is coupled to array of input filters **105** of digital front-end circuit **130**. Array of input filters **105** is coupled to pulse detector circuit **110**, and pulse detector circuit **110** is coupled to common mode rejection circuit **115**. Common mode rejection circuit **115** is coupled to pulse data queuing and transmission circuit **120**, and pulse data queuing and transmission circuit **120** is coupled to pulse processor **140** of guidance circuit **135**. Pulse

10 processor **140** is coupled to common mode rejection filter **115**, angle determination circuit **145**, and automatic gain control and threshold circuit **150**. Automatic gain control and threshold circuit **150** is coupled to a variable gain amplifier (not shown) and to pulse detection circuit **110**. Angle determination circuit **145** is coupled to a computer (not shown). Storage media **155** is coupled to angle determination circuit **145**.

15 In one exemplary embodiment, each of plurality of digitized data channels **101** may represent an incoming digitized signal from a sensor or a transducer, such as, for example, a photodiode or the like.

In practice, digital front-end circuit **130** may be an integrated circuit or a programmable circuit, such as, for example, a programmable logic device (PLD) or a

20 field-programmable gate array (FPGA). When digital front-end circuit **130** is a programmable circuit, a program, such as that presented below and discussed in detail with reference to **FIG. 2**, creates an apparatus in accordance with the present invention

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that operates in accordance with the methods of the present invention. In the alternative, digital front-end circuit **130** may be hard-wired or may use predetermined data tables, or may be a combination of hard-wired and programmable circuitry.

When in operation, a plurality of incoming digitized signals enters digital front-end circuit **130** via array of input filters **106**. An input filter may be, for example, high-pass filters to correct for an analog-to-digital conversion effect. Next, the plurality of signals is fed into pulse detection circuit **110**, which identifies pulses according to a threshold set by automatic gain control and threshold circuit **150**, delivering a plurality of unfiltered data streams to common mode rejection circuit **108**. At common mode rejection circuit **108**, a common mode interference is filtered out of the data streams, and the data streams are transmitted to guidance circuit **135** via pulse data queuing and transmission circuit **120**.

Guidance circuit **135** may be a processor, a digital signal processor (DSP), a computer, or the like. Program storage media **155** may be any type of readable memory including, for example, a magnetic or optical media such as a card, tape or disk, or a semiconductor memory such as a PROM or FLASH memory. In one embodiment, program storage media **155** may include a stored seeker response data.

When in operation, guidance circuit **135** processes streams of pulses and determines the direction of a source by calculating angles based on pulse amplitudes and using a calibration data such as, for example, a seeker's response data stored in storage media **155**. The operation of guidance circuit **135** is known to one of ordinary skill in the art and needs not be detailed here.

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Referring to **FIG. 2**, a flowchart of one embodiment of a common mode interference filtering method **200** is depicted. Method **200** may be performed by common mode rejection circuit **115** of **FIG. 1A**. In one embodiment, the method monitors a plurality of data channels for pulses, performs a calculation with a number of channels that have the lowest voltage level, and compares this result with the channel that has the highest level.

In step **205**, a pulse is received. In step **210**, a subset of N channels with the lowest levels among the plurality of data channels is identified, and these lowest levels are summed into a summed level, where N is an integer. In one embodiment, N is equal to 3 – that is, 3 data channels with the 3 lowest levels are summed. In step **215**, a sensitivity factor provided by the pulse processor **140** to the common mode rejection circuit **115** is used to multiply the sum of N channels. In one embodiment, the sensitivity factor is set to 1. In another embodiment, the sensitivity factor is equal to 2. In step **220**, the summed level is compared to the highest level present among the plurality of data channels. If the sum of lowest N channels if larger than the highest channel level, the pulses on every channel are deleted. Otherwise the channels data is transmitted to guidance circuit **140** detailed in **FIG. 1B**. Next, control passes to step **235** and the method waits for the next pulse.

In one embodiment, method **200** is repeated several times. In another embodiment, method **200** is repeated at every data point. The invention may include performing method **200** every 10 ηs (100 MHz). The sensitivity factor may be changed

by pulse processor **140** as a function of the false alarm rate, that is, the rate at which method **200** deletes actual data instead of filtering only common mode interference.

Software or computer instructions configured to carry out one or more steps of method **200** may be loaded onto a computer readable medium. One of ordinary skill in the art will understand that computer readable medium may take many forms, including any data storage device that can store data that can thereafter be read by a processor, a computer or a computer system, including, for example, a disk, such as a floppy disk, a zip disk, or the like; read-only memory; random access memory; CD-ROMs; magnetic tape; optical data storage devices, SMARTMEDIA ® cards; flash memory; compact flash memory; and the like. The computer readable medium can also be distributed over network-coupled computer systems so that the computer readable instructions are stored and executed in a distributed fashion. For example, the computer readable medium may also take the form of a carrier wave such as, for example, signals on a wire (e.g., signals downloaded from the Internet) or those that are transmitted electromagnetically or through infra red means.

Shown in the computer program listing appendix (*see* CD) is an exemplary source code written in Altera Hardware Description Language that is suitable for carrying out steps described above, and which may be used in conjunction with a field programmable gate array (FPGA) such as, for example, the APEX 20KE FPGA (EP20K200E) from Altera Corporation. The code is an example of how to filter a common mode interference according to the methods detailed in **FIG. 2** and described above. This code is exemplary and does not limit the scope of the claims. It simply represents one specific embodiment

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for carrying out steps associated with the present methods and is included for the convenience of the reader in this regard. Those of ordinary skill in the art having the benefit of this disclosure will recognize that a wide variety of computational techniques and/or different types of corresponding source code may be used in implementing the present methods.

Referring to **FIG. 3**, a graph of filtered and unfiltered simulated data streams **400** is depicted illustrating an aspect of the invention. The horizontal axis is time and the vertical axis is the amplitude. Plurality of incoming channels **301A-304A** containing common mode interference is processed by common mode rejection circuit **115** of **FIG. 1A** operating as described above. Resulting filtered data streams **301B-304B** contain only data pulses **310** in channel **301B**, and are free of the common mode interference originally present in every incoming channel **301A-304A**.

The individual components described above need not be made in the exact disclosed forms, or combined in the exact disclosed configurations, but could be provided in any suitable form, and/or combined in any suitable configuration. It will also be clear to those of ordinary skill in the art substitutions, modifications, additions and/or rearrangements of the features of the inventive methods and devices may be made without deviating from their scope, which is defined by the claims and their equivalents. The appended claims are not to be interpreted as including means-plus-function limitations, unless such a limitation is explicitly recited in a given claim using the phrase(s) "means for" and/or "step for," respectively.

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